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THE EFFECT OF NUMBER OF ALLOWED TARGET CHOICES UPON THE TARGET-REPORTING BEHAVIOR OF RADAR OBSERVERS

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NOVEMBER 1969

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13. ABSTRACT

Studies which impose no limit upon the number of responses an observer can make usually find high false-positive rates. The present study examines observer performance when limits are imposed. Forty-two bombardier-navigators were divided into three target choice groups: 20, 40, and no limit. They examined a moving strip of side-looking radar imagery rear-projected onto a 14 by 14-inch display screen at a scale of 1:130,000. The displayed image covered a 25-mile wide strip of terrain and moved at 12.3 inches/minute, simulating a 1320-knot mission lasting 27 minutes.

The number of targets reported increased significantly when more choices were allowed; however, there were even larger increases in false positives. No particular type of target was responsible for this. Only in the most limited choice group did accuracy increase with mission duration. Early in the test runs groups attained different but relatively constant rates of responding. It is concluded that the imposition of realistic limits upon the number of allowed choices greatly improves accuracy. Studies that do not impose limits on number of choices give results with too many false targets.

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False Positives						
Accuracy						
Completion						
Performance						
Scoring						

SUMMARY

Studies which impose no limit upon the number of responses an observer can make usually find high false-positive rates. The present study examines observer performance when limits are imposed. Forty-two bombardier-navigators were divided into three target choice groups: 20, 40, and no limit. They examined a moving strip of side-looking radar imagery rear-projected onto a 14 by 14-inch display screen at a scale of 1:130,000. The displayed image covered a 25-mile wide strip of terrain and moved at 12.3 inches/minute, simulating a 1320-knot mission lasting 27 minutes. Results show that:

1. The percentage of the available targets that are detected increases appreciably and significantly with each increase in the number of allowed target choices. However, the number of nontargets mistaken for targets also increases appreciably and significantly.

2. With increase in number of allowed target choices, the number of nontargets mistaken for targets increases at a faster rate than the increase in number of detected targets. This means that accuracy decreases.

3. The largest decrease in accuracy for all types of targets, either combined or separately, occurs in going from the 40-choice to the no-limit choice condition. Unlimited freedom to respond ruins accuracy.

4. From the beginning to the end of the test runs, only the most limited (20-choices) group exhibits any trend in accuracy. For this group, accuracy increases with duration. Also, for this test group, there is a positive and significant, but not high, correlation between accuracy and number of choices that have been made.

5. Along the displayed flight path there is a high, positive, and statistically significant correlation between rate of responding (rights plus wrongs) and frequency of available targets, and between number of targets detected and frequency of occurrence of targets.

6. Rates of responding of groups with different numbers of allowed target choices are significantly different. However, when allowance is made for fluctuation in frequency of occurrence of targets along the test run, these rates exhibit little fluctuation. This relatively constant response pace is attained early in the test run.

7. Subject behavior is consistent with the hypothesis that when subjects believe that more care or caution in target selection can be profitably exercised, they behave accordingly.

8. The probability that a target will be detected varies widely with the type of target. However, rate of increase in percentage of targets detected with increase in number of permitted choices varies in a similar way for the four types of targets.

9. Accuracy varies widely with type of target. However, rate of decrease of accuracy with increased number of allowed choices is about the same for the four types of targets. No one type of target is particularly responsible for the large increase in errors when more targets are allowed.

10. All test groups found the majority of the targets on the upper half of the display.

11. The average distance traveled on the display screen by targets prior to their detection does not vary with change in the number of allowed choices. Restrictions upon number of choices neither speeds up nor slows down speed of reaction to targets.

12. The increase in detections with increase in number of allowed target choices is largely due to targets of low visibility. When no limit on number of responses was imposed, many more (44%) additional targets not reported by anyone in the most limited group are reported.

This study demonstrates that limiting the number of targets that may be chosen can greatly reduce the number of nontargets mistaken as targets, although the reduction is achieved at a cost (understandably) in the percentage of actual targets detected. Response restrictions could make useful some rapid reconnaissance and reconnaissance/strike systems heretofore considered to be unfeasible due to the high false-positive rates of certain types of prior studies and analyses. Further research is needed, however, on the utility-of-choice restrictions versus confidence judgments.

FOREWORD

This report was prepared in the Human Engineering Division of the Aerospace Medical Research Laboratory. The work was performed jointly under Advanced Development Program 665A and Project 7184, "Human Performance in Advanced Systems," Task 718404, "Human Engineering Design Criteria for Reconnaissance and Reconnaissance/Strike Systems."

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This technical report has been reviewed and is approved.

C. H. KRATOCHVIL, Colonel, USAF, MC
Commander
Aerospace Medical Research Laboratory

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SECTION I

INTRODUCTION

Reconnaissance systems are used to discover potential targets and to gain new information on known targets. Strike systems deliver explosives or other material upon targets to damage, destroy, or otherwise reduce the military threat that they represent. Reconnaissance/strike systems combine both functions, striking new targets that they find or known targets which, upon inspection, are found to require such action.

The number of targets found as well as the observer's confidence and accuracy depend upon how many tasks in addition to target search that he must perform, his instructions, motivation, etc., as well as on the nature, numbers and types of target that come into view on his display. Research that allows observers an unlimited (or at least unspecified) number of target choices, whether or not he reports a confidence judgment with each response, will not necessarily lead to valid conclusions about the behavior of operational systems.

Numerous studies have been reported on the behavior of observers searching for targets of opportunity. In some studies, observers have been required to state how confident they were of the correctness of each response, and a check was made of the confidence categories. (Bate and Self, 1968 a, b; Sadacca, 1960). In all of these studies, a significant increase in accuracy (proportion of responses correct) resulted from accepting as targets only those responses given the highest confidence level rating available to the subject. Because of limited weapon loads in actual flight situations, it typically would not be possible to strike all objects that appear to be targets, or even all those at the highest expressed confidence level. Behavior of an observer with only a few target choices allowed may be quite different from his behavior in an unlimited choice situation. For these reasons, it is important to examine the effects of such limitations upon observer behavior.

In operational reconnaissance/strike system, particularly when searching for targets-of-opportunity, i.e., new targets, the radar observer does not know how many targets he will encounter. However, he may know how long he will be flying over hostile territory, and he certainly knows how many strike weapons he has on his aircraft. In the present study, both flight time (mission duration) and the strip of territory sensed by the radar and depicted upon the display are held constant. The number of allowed target choices at the observer's disposal (number of strike weapons) is varied.

The present study examined several trends in performance as number of allowed target choices was reduced. The results are intended to indicate to what extent, if any, the results of other studies not using limited target choices must be modified when applied to the design or evaluation of systems.

At the start of the study it was hypothesized that: (1) accuracy will increase as the number of target choices assigned to the observer decreases, (2) observers will "pace" themselves so as to utilize all or nearly all of their available weapons, and (3) accuracy will vary directly with the accuracy of pacing, e.g., an observer will be reckless near the beginning of a run with a large number of weapons or near the end of a run when several weapons are unexpended. If he is well ahead, i.e., has a long time to go and has only a few weapons left, he will be extremely cautious, (4) observers who have a limited number of allowed choices will be more accurate than observers told only to find targets.

SECTION II

PROCEDURE

EXPERIMENTAL DESIGN

Forty-two test subjects were randomly divided into three groups, each containing 14 subjects. One group had no limit placed on the number of objects that its members could designate as targets; members of the second group could select up to 40 objects; and observers in the third group were limited to 20 objects. The experimental design was a single factor (number of allowed choices) randomized-groups design with each subject being tested only once. Statistical analysis of the data was conducted in accordance with procedures applicable to a mixed model experimental design.

The number of target choices assigned to the three choice groups was selected to cover a wide range of values and to identify any important performance trends. The unlimited choices case was selected to represent the condition prevailing in most previously published studies; namely, no limit on the permitted number of targets that subjects could designate. To make the task more meaningful for the subjects, the target choice limits were put in terms of number of available weapons to strike detected targets, i.e., in the 20-choice case they were told there were only 20 weapons available to strike detected targets, etc.

EXPERIMENTAL CONTROLS

The following experimental controls were maintained throughout the experiment:

1. All subjects received intensive training on side-looking radar. For a description of the training procedures used by this laboratory on side-looking radar, see VanAusdall and Self (1964).

2. All subjects received written instructions at the beginning of the test, and each was given a few minutes practice with the experimental apparatus.

3. The illumination level of the projected radar imagery, rate of motion, and projector focus were verified prior to each test.

APPARATUS

<u>Projection Device</u>: A moving strip of high resolution side-looking radar film was projected onto a 14 by 14-inch rear-projection screen by a Model 100A

optical projector built for this laboratory by the Hughes Aircraft Company. It contains a variable speed film drive mechanism which allows a wide range of aircraft speeds to be simulated. However, only the 12.3 inches/minute speed was used.

Response Recording: The console in which the projector was housed had a response panel with 14 push-button switches located to the right of the viewing screen. The console is shown in fig 1. The subject placed the tip of an illuminated stylus upon the screen image of each target and depressed the appropriate switch to indicate the type of target. If, after activating the target-type switch, the subject decided (before pushing the record switch) that he had made an error, he could depress an "error" erase switch which canceled the target name readout data. If the subject believed that he had pushed the correct target-type switch, he depressed the "record" switch, activating a 35 mm data camera located over his right shoulder. This camera recorded the position of the stylus on the screen image, and the target-type readout information. The readout information was displayed to the data camera as illuminated digits on a small screen to the left of the display screen.

Remaining Flight Time: By reference to an illuminated clock located slightly above the response panel on the right of the viewing screen, the subject kept track of the remaining flight time. Simulated flight duration (viewing time) was 27 minutes for all conditions.

Weapon Count: The number displayed on an illuminated digital counter located to the right of the screen decreased by one each time an object was designated by the observer as a target. When the number of responses made by the subject was equal to the permitted number of target choices, the counter read zero, and no more responses were allowed. Thus the counter kept the subject informed of the number of "strikes" that he had left. It was his weapon supply record.

The same 5-inch-wide strip of high resolution side-looking radar film, collected by an APS-73 (XH-3) radar set, was used for all subjects. Figure 2 is an example of the general type of radar imagery used in this study; however the imagery shown in figure 2 is at a different scale than that actually used in the study. The radar imagery displayed to test subjects was at a scale of 1:130,000 and was a ground swath 25 nautical miles wide. The radar picture moved from the top to the bottom of the display screen at approximately 12.3 inches per minute, simulating an aircraft speed of 1320 knots.

Assisted by Series 200 Navigation Charts, various city and state maps, and ground truth information from other sources, the investigators searched the radar film. Sixty-three targets were judged to be visible on the display screen (Appendix I). The four types of targets that the subjects were asked to find and identify were: (1) airfields, (2) dams, (3) railroad yards, and (4) tank farms or petroleum refineries.

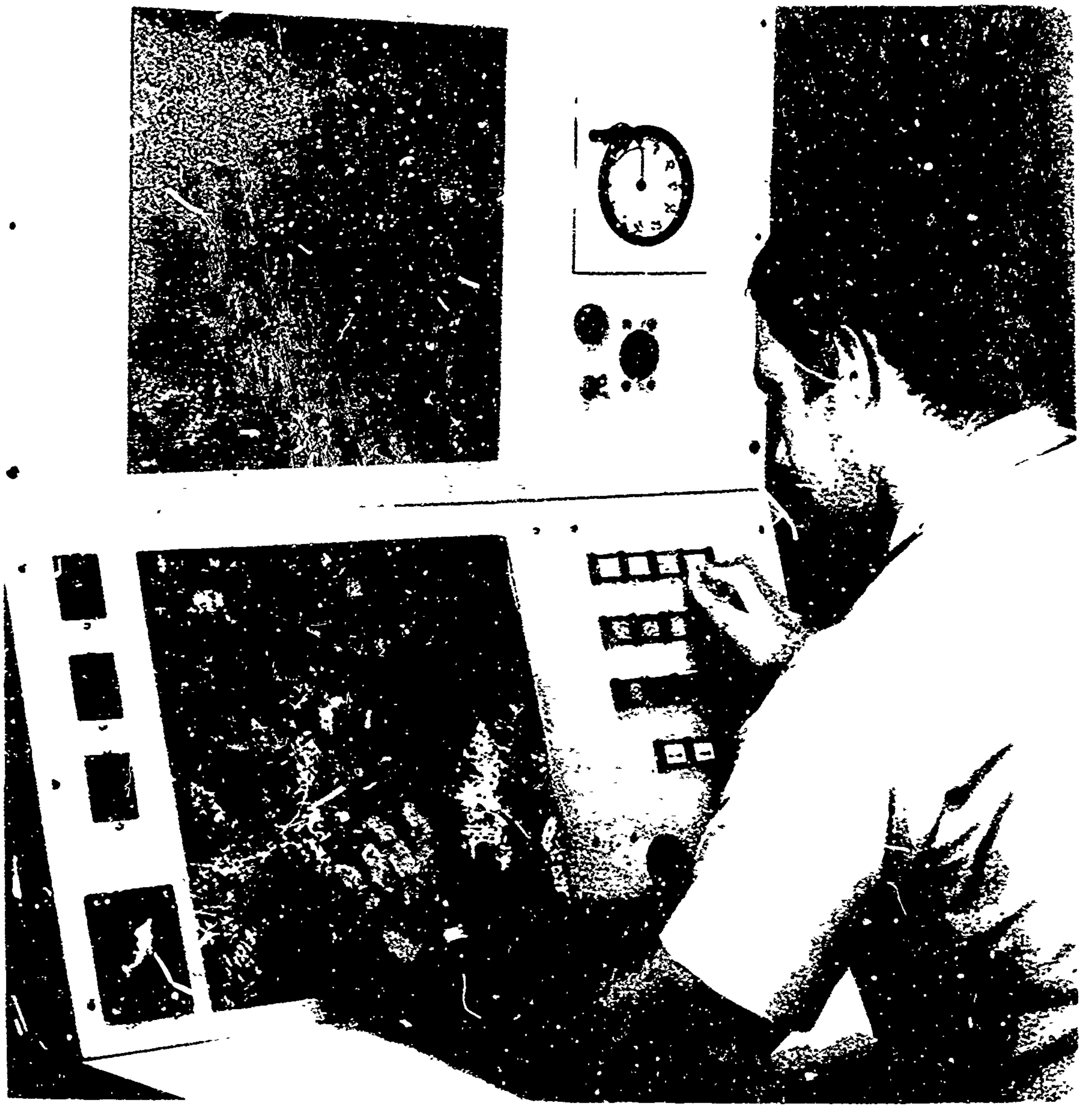

Figure 1. An Observer at Work at the Display Console.

Figure 2. An Example of the Type of Image Produced by a Side-Looking Radar Sensor.

SUBJECTS AND TEST INSTRUCTIONS

The subjects were 42 navigator-bombardiers from the USAF Strategic Air Command. At the beginning of each experimental trial, each subject received a set of typewritten instructions (See Appendix) describing the situation and the task.

There were three sets of instructions, but two were alike except that one said "Your aircraft carries 20 bombs (or missiles)", where the other set of instructions stated that 40 weapons were available. The third set of instructions imposed no limits.

MEASURES OF PERFORMANCE

Target Recognitions and False Positive Responses: A target recognition was recorded each time a subject pointed to one of the 63 recognizable targets and depressed the correct target-type switch and record switch. A false positive was recorded each time a subject pointed to a nontarget object and depressed a target-type switch and the record switch.

Number of Incorrect Responses: An incorrect response was recorded when the subject designated one of the 63 targets, but assigned the wrong target name to it. Since these misclassifications were fairly uniform across treatments, and amounted to less than 1% of all responses, they were disregarded in the statistical analyses.

Screen Travel: Measurements were recorded for the distance traveled down the screen by targets and nontargets prior to depressing the record switch.

SECTION III

RESULTS AND DISCUSSION

NUMBER OF RESPONSES TO TARGETS AND TO FALSE POSITIVES

The number of responses to real targets and the number of responses to nontargets mistaken for real targets for individual subjects is given in table I. In the 20-choice group,* 13 of the 14 subjects used all 20 allowed choices, and 1 subject used only 19. In the 40-choice group,** 4 subjects used all 40, 1 used 39, 6 used 38, 2 used 37, and 1 used 29, i.e., only 3 used less than 38 of the 40 allowed. The footnotes explain slight discrepancies between the above data and the tables. Clearly, most subjects in both of the limited choice groups expended all of their supply of available weapons (or allowed choices), and the remaining subjects expended almost all weapons.

The test group with no limit on number of allowed target choices may be regarded as a control group. The mean number of choices for this group was 76.6, which is about twice the mean for the 40-choice group (mean 37.7). The nature of this increase is obvious from examination of figure 3. This figure shows the number of responses to targets, the number of responses made to nontargets mistaken for targets, and the sum of the two types of responses. While there is a small increase in the number of genuine targets detected, there was a large increase in the number of nontargets mistaken for targets, i.e., in false positives. The result of this large increase in false-positive responses upon accuracy, defined as the proportion of target designation responses that are made to genuine targets, is discussed in another section of this report.

Bartlett's homogeneity of variance test (1934) indicated significant heterogeneity of variances for both number of targets detected and number of nontargets mistaken for targets. Homogeneity of variances was achieved, as shown by Bartlett's test, when a logarithmic transformation was applied to the data.

Analysis of variance (see tables II and III) performed on the log-transformed data for number of targets detected and for number of nontargets mistaken for targets yielded $\underline{F}$ ratios of 72.98 and 145.4, respectively. Both of these are

---

* In this group, 4 of the 399 responses made, or 1% of them, were unscorable due to overexposure in the data camera.

** Here, 2 of the 530 responses made, or 0.38% of them, were unscorable: one due to overexposure, and one due to the subject's head blocking the view of the camera.

statistically significant (P .001). Analyses of variance on the untransformed or raw data resulted in the same finding, yielding $\underline{F}$ ratios of 55.9 and 79.9, respectively, both statistically significant (P .001).

Numbers of reported detections and numbers of false positives both varied significantly with the number of allowed target choices.

Using the log-transformed scores, the number of responses made to real targets in the three test groups were analyzed by Duncan's New Multiple Range Test (NMRT) (Duncan 1955). Transformed scores for the number of false positive responses were also analyzed in the same way. Duncan's Test showed that the average numbers of targets detected by the three groups were all significantly different from each other (P .05). The average number of false positives were also significantly different from each other (P .05).

Duncan's Test and an examination of the means (averages) indicated that each increase in number of allowed target choices resulted in a statistically significant increase in both number of targets that were detected and number of false positives.

PERCENTAGE OF AVAILABLE TARGETS DETECTED

By definition, percentage of available targets detected is 100 times the number of targets detected divided by the number of targets available. Thus, it is a linear transformation of number of targets detected. It follows that the results of the analysis of variance for numbers detected will hold for percentages detected. In short, with every increase in number of choices allowed there was a statistically significant increase in percentage of available targets that were detected.

Incidentally, since 50 targets were actually detectable in the sense that one or more of the 42 subjects found them, numbers detected can be converted to percent detected simply by multiplying by two. Using this relationship and the mean number of detections in table I reveals that the average percentage of targets detected were 29 4, 46.6, and 57.0 percent for the 20, the 40 and the no limit test groups, respectively.

OVERALL ACCURACY OF RESPONSES

The ratio of number of correct responses that are made, i.e., the proportion of responses that represents detected targets, is called response accuracy. Usually it is abbreviated simply to "accuracy" and is expressed in decimal form.

Earlier, it was noted that when the number of target choices allowed increased, the increase in the number of false positives exceeds the gain in detected targets (see fig 3). Also, when no limit was set to the number of

TABLE I

NUMBERS OF GENUINE TARGETS DETECTED, NUMBERS OF FALSE POSITIVES, AND ACCURACY SCORES FOR INDIVIDUAL SUBJECTS

	20-Choice				40-Choice				No Limit			
	Targets Detected	False Positives	Sum	Accuracy	Targets Detected	False Positives	Sum	Accuracy	Targets Detected	False Positives	Sum	Accuracy
	18	2	20	.9000	20	18	38	.5263	19	25	44	.4318
	15	5	20	.7500	22	18	40	.5500	23	19	42	.5476
	15	5	20	.7500	22	6	28	.7857	26	45	71	.3662
	14	6	20	.7000	23	15	38	.6053	30	49	79	.3797
	17	3	20	.8500	24	16	40	.6000	32	45	77	.4153
	16	4	20	.8000	22	16	38	.5789	29	46	75	.3867
	14	4	18	.7778	22	18	40	.5500	26	35	61	.4262
	15	4	19	.7895	17	20	37	.4595	26	43	69	.3768
	11	7	18	.6111	26	12	38	.6842	28	60	88	.3182
	16	4	20	.3000	28	12	40	.7000	37	45	82	.4512
	14	6	20	.7000	24	13	37	.6486	28	67	95	.2947
	12	8	20	.6000	27	10	37	.7279	30	58	88	.3409
	13	7	20	.6500	24	14	38	.6316	38	57	95	.4000
	16	4	20	.8000	25	14	39	.6410	27	80	107	.2523
Sum	206	69	275	10.4784	326	202	528	8.6908	399	674	1073	5.3879
Mean	14.71	4.93	19.64	.7485	23.29	14.43	37.71	.6208	28.50	48.14	76.64	.3849
Median	14.83	4.50	19.86	.7639	23.50	14.50	38.10	.6185	28.00	45.50	73.00	.3832
S.D.	1.90	1.69	.75	.0873	2.84	3.72	3.02	.0857	4.97	15.95	18.59	.0726

TABLE II

ANALYSIS OF VARIANCE OF NUMBER* OF TARGETS DETECTED

Source of Variance	Mean Square	d.f.	F	Meaning
Between Groups	.597	2	72.98***	Number of targets detected varies significantly with number of choices allowed.
Within Groups	.160	39		

* Logarithmically transformed data was used.

*** Statistically significant at the .001 level.

TABLE III

ANALYSIS OF VARIANCE OF NUMBER* OF NONTARGETS THAT WERE MISTAKEN FOR TARGETS

Sources of Variance	Mean Square	d.f.	F	Meaning
Between Groups	3.431	2	145***	Number of false positives varies significantly with the number of choices allowed.
Within Groups	.024	39		

* Logarithmically transformed data was used.

*** Statistically significant at the .001 level.

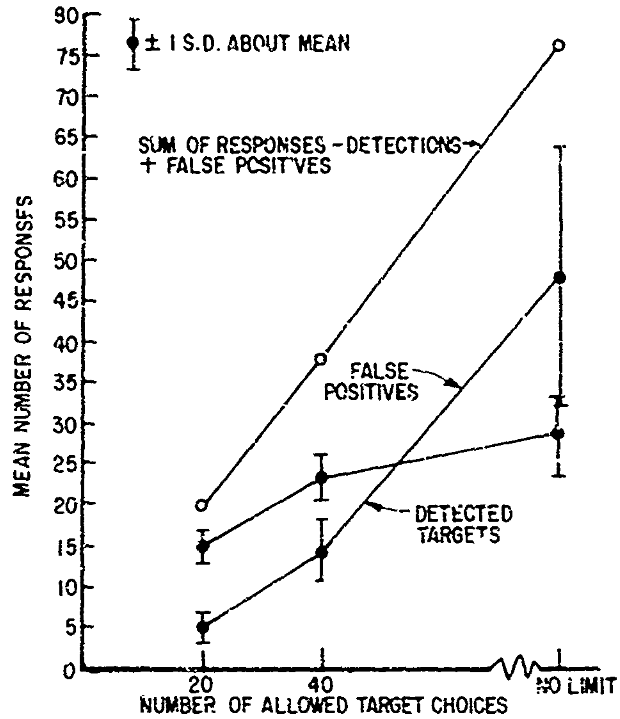

Figure 3. Average Number of Responses for Groups With Different Numbers of Allowed Target Choices.

choices that were permitted, the number of false positives exceeded the number of genuine targets that were detected. Thus, accuracy decreased when more choices were allowed.

The individual accuracy scores for the 42 subjects are given in table I. The arithmetic means, which are at the bottom of the table, are .748, .621, and .385 for the 20-choice, the 40-choice, and the no limit test groups, respectively. In figure 4 these averages, plotted against number of allowed target choices, show that accuracy decreased appreciably when subjects were allowed more choices. The accuracy of the no-limit test group is especially low: Accuracy is only about half as high for this group as it is for the two limited-choice groups. An object designated as a target by the no-limit group is twice as likely to be a nontarget as it is to be a target. With the two limited-choice groups, a designated object is more likely to be a target than to be a nontarget object.

Since accuracy scores are proportions, an arc sine transformation of the scores was needed to secure homogeneity of variance so that the data could be analyzed by analysis of variance. This analysis is summarized in table IV. The obtained $\underline{F}$ of 62.9 is statistically significant at the .001 level, indicating that the number of available weapons (permitted target choices) has an effect

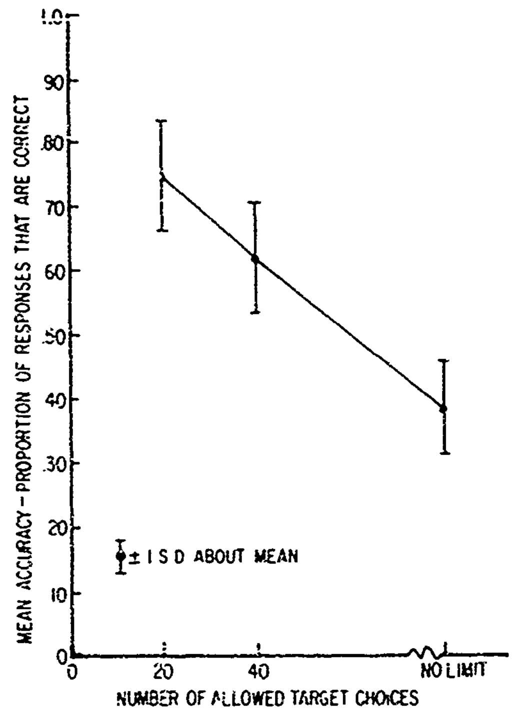

Figure 4. Average Accuracy With Different Numbers of Allowed Target Choices.

upon accuracy of responses. Table V summarizes an analysis of variance of untransformed scores and its significant (P .001) F also leads to the same conclusion. Multiple comparisons of the response accuracies of the three choice groups by means of Duncan's Test (NMRT) reveals that all three groups are significantly (P .001) different from each other in accuracy. Each increase in number of allowed target choices resulted in a significant decrease in the accuracy of responses.

DISTRIBUTION OF RESPONSES OVER THE TERRAIN

Subjects were told at the start of the mission (experimental trial) that they would be in simulated flight over "enemy" territory for 27 minutes. During the mission the time clock and response counter were always on display. However, the territory was unfamiliar to the subjects, and they were told only that the strip of terrain was in the United States. Also, they did not know how many targets might appear during the mission. The two limited-choice groups were told to make the best use of their supply of weapons (See Instructions in the Appendix).

With these instructions and conditions, several strategies are possible. One procedure would be to use up all of the available weapons (choices) as quickly as this could be done without undue waste of munitions. Another strategy

TABLE IV

ANALYSIS OF VARIANCE OF ACCURACY* SCORES

Source of Variance	Mean Square	d.f.	$\underline{F}$	Meaning
Between Groups	1725.52	2	62.9***	Accuracy varied significantly with number of choices allowed.
Within Groups	27.43	39		

* Arc sine transformed scores were used. Accuracy is proportion of responses that were made to genuine targets.

*** Statistically significant at the .001 level.

TABLE V

ANALYSIS OF VARIANCE OF ACCURACY SCORES
(USING NO TRANSFORMATION)

Source of Variance	Mean Square	d.f.	$\underline{F}$	Meaning
Between Groups	.4765	2	70 ***	Accuracy varied significantly with number of allowed choices
Within Groups	.0068	39		

*** Statistically significant at the .001 level.

would be to be very cautious early in the simulated mission and then to respond rapidly (pile up responses) and almost recklessly near the end of the mission in an attempt to unload the remaining weapons. Still another approach would be to adopt a somewhat uniform rate of expenditure (pace) that would fluctuate with the frequency of occurrence and the difficulty or obviousness of the targets. Such a manner of responding would be intended to spread responses over the entire mission. Other strategies are easily conjectured.

Since all subjects responded to what they thought were targets, it is instructive to examine all responses (responses to genuine targets plus responses to nontargets mistaken for targets) per consecutive fifth of the displayed terrain. The data is given in table VI, and is plotted in figure 5. The curve labeled "possible targets" plots the 63 targets that were judged, prior to testing observers, as being detectable, while the curve labeled "available targets" plots the 50 targets that were each responded to by one or more of the entire pool of 42 test subjects. These two curves plot numbers of available targets distributed along the Flight Path rather than number of responses, as do the other curves.

TABLE VI

AVERAGE NUMBER OF RESPONSES* PER SUCCESSIVE FIFTH OF THE TERRAIN STRIP

Fifth of Terrain Strip	TEST GROUP 20-Choices Mean	20-Choices S.D.	40-Choices Mean	40-Choices S.D.	No-Limit Mean	No-Limit S.D.	Number of Available** Targets	Number of Possible*** Targets
First	6.86	2.28	10.29	3.50	20.79	7.30	14	18
Second	2.71	1.33	5.36	1.69	12.36	5.42	6	8
Third	4.29	1.38	6.86	2.14	14.00	5.63	9	12
Fourth	5.07	1.90	10.86	2.48	18.93	5.18	16	18
Fifth	0.71	0.91	4.36	2.47	10.57	2.53	5	7

* Responses include both detected real targets and false positives.

** Available in that one or more of the 42 subjects made a response to the target.

*** Possible in that this number of targets was determined to exist in image truth, i.e., were judged prior to the experiment to be detectable.

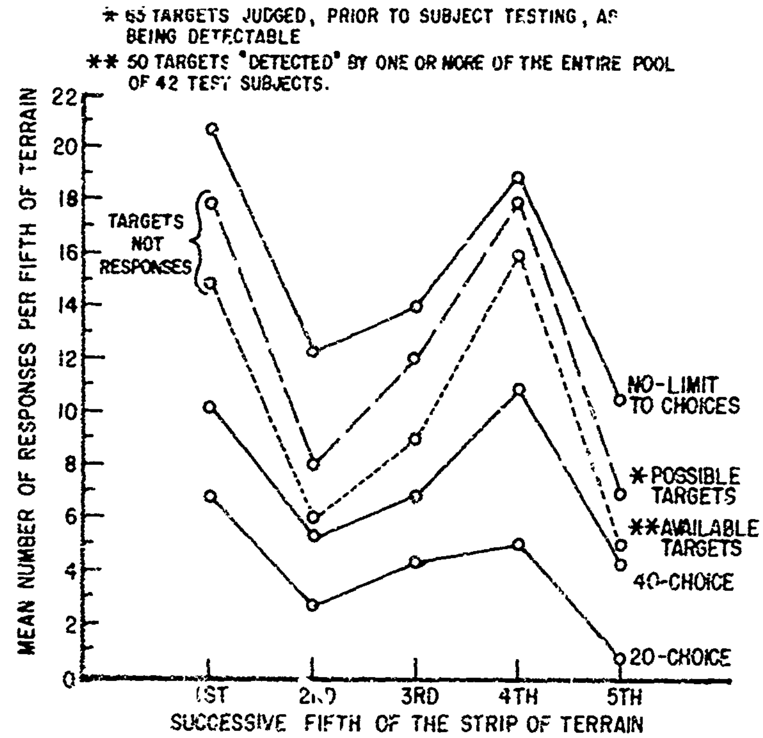

Figure 5. Average Number of Responses Per Successive Fifth of the Strip of Terrain That Was Displayed, Showing the Distribution of Responses Over the Duration of the Simulated Flight. Responses Include Both Target Detections and Nontarget Objects Mistaken for Targets.

Examination of the figure reveals that:

1. All of the curves on the graph are approximately parallel to each other. There are no intersections or crossovers. Whenever more targets are available, more responses are made.

2. In every fifth of the terrain, the number of "possible" targets exceeds the number "available" by an approximately constant amount.

3. The number of responses (objects designated as targets) made by the no choice limit group exceeds the number of targets present by either the possible or available criteria in every one of the five intervals.

4. In every fifth of the terrain strip more responses are made by groups having a larger number of total allowed choices.

The degree of parallelism of the curves can be examined analytically by calculating the product moment coefficient of correlation between number of responses and number of targets present. The correlation coefficients are given in table VII. All correlations are large, positive, and significantly (P .05) greater than zero. Thus, the covariation of number of responses and number of targets present is shown by statistics to not be a chance result, which is also true for the increase in number of responses as the total number of permitted choices increases. The parallelism of the curves in the figure and the consequent high correlations indicate that the pattern of responding, which may be referred to as "pacing," merits further examination.

TABLE VII

PRODUCT MOMENT CORRELATIONS BETWEEN NUMBER OF RESPONSES PER SUCCESSIVE FIFTH OF THE STRIP OF TERRAIN AND THE NUMBER OF TARGETS PRESENT PER FIFTH

TEST GROUP	PRODUCT MOMENT CORRELATION COEFFICIENTS	
	AVAILABLE* TARGETS	POSSIBLE** TARGETS
20-choice	.8643***	.9754
40-choice	.9958	.9952
No limit	.9518	.9968

* 63 targets in all were judged prior to tests to be available.

** 50 targets were possible in that they were found and reported by one or more of the 42 subjects. These targets each had a detection probability equal to or greater than .024.

*** By one-tailed tests of statistical significance all correlation coefficients in the table are significantly greater than zero at the .01 level of significance except the one with three asterisks which is significant at the .05 level. Thus, all six relationships are greater than could be expected by chance alone.

To examine this pacing, responses were summed up through successive fifths of terrain. This summing smooths irregularities and makes for simpler comparison of pacing effects. Table VIII gives the data, and it is shown graphically in figure 6. The solid lines are least-squares best fits to the data. They show what performance could be expected if all choices were expended at a constant rate along the terrain. Note how well the data points fit the lines. It is logical to call the lines "patterns of pacing." The test groups clearly differ in rate of responding (slope of the curves) and height of the curves above the baseline, but do not differ in pattern or shape. The test groups start out at different rates of responding, and the different rates are maintained with little fluctuation when allowance is made for differences in numbers of targets available per fifth.

TABLE VIII

MEAN NUMBER OF RESPONSES* ACCUMULATED**
UP THROUGH SUCCESSIVE FIFTHS OF THE TERRAIN

	MEAN OF DETECTED TARGETS AND FALSE POSITIVES		
Fifths of The Terrain	TEST GROUP		
	20-Choices	40-Choices	No-Limit
First One	6.86	10.29	20.79
First Two	9.57	15.65	33.15
First Three	13.86	22.51	47.15
First Four	18.93	33.37	66.08
All Five	19.64	37.73	76.65

* Responses include detected targets plus nontargets designated as targets.

** The means in this table were obtained by summing group means from table VI.

Note that there were enough detectable targets and objects not distinguishable from targets by the subjects for all individuals in the 20-choice and 40-choice groups to very quickly use up all or almost all allowed choices. The observed patterns of pacing might not have held if conditions had been otherwise; for example, if the last half of the flight had contained only a few possible targets.

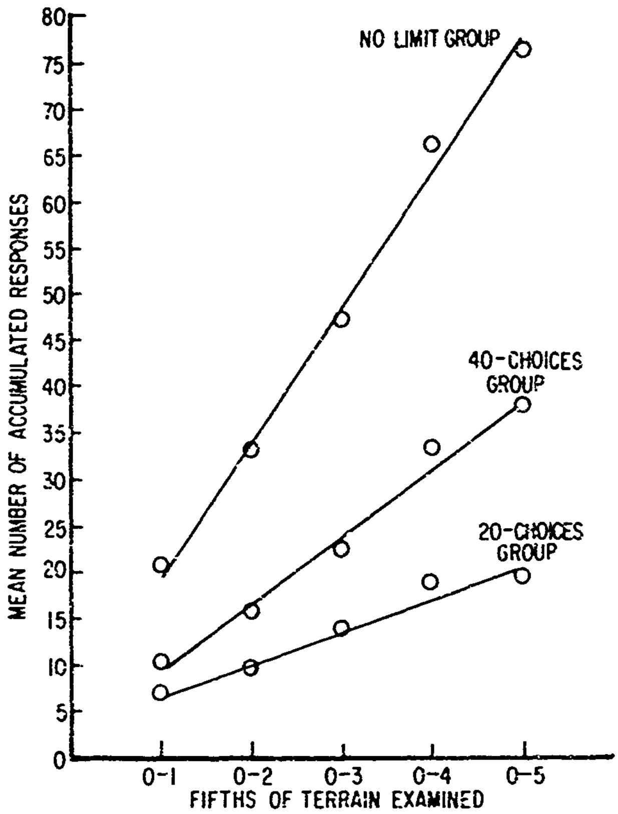

Figure 6. Summed Average Number of Responses Through the Course of the Test Run by Successive Fifths of Terrain.

That subjects in the 20-choice group spread their responses over the entire path while the 40-choice group used 20 choices by the time they were halfway along the flight path is significant. Subjects were not told to spread (or not to spread) their responses over the entire flight path. How strongly the results are affected by the target distribution and how much is attributable to deliberate attempts to pace is unknown. However, the large increase in accuracy as the permitted number of target choices decreased (a point discussed elsewhere in this report) indicated that subjects were more cautious when they believed that more caution in target selection could be profitably exercised. When they had a larger number of allowed choices (available weapons), they acted as if greater recklessness were justified, presumably to avoid ending the mission with several unexpended weapons.

The generality of the finding of uniformity (with correction for target availability) along the entire strip of terrain of rate of choosing targets is unknown. Also, the generality of the high correlations between number of responses and number of available targets is unknown. The authors believe that both findings will hold up in subsequent research that further examines the variation in distribution of targets over the imaged terrain. Such research should be done with various sets of instructions.

DISTRIBUTION OF TARGET DETECTIONS OVER THE TERRAIN

The previous section showed that total number of responses, including both detections and false positives, accumulated over the test session at a highly uniform rate, and these rates increased with the number of allowed choices. When detected targets alone are considered, exactly the same conclusions can be drawn. This is true when detections by either successive groups of ten available targets or by successive fifths of terrain. This may be readily seen from examination of figure 7, which is plotted from the data in tables IX and X. The two sets of curves, solid and dashed, are almost identical.

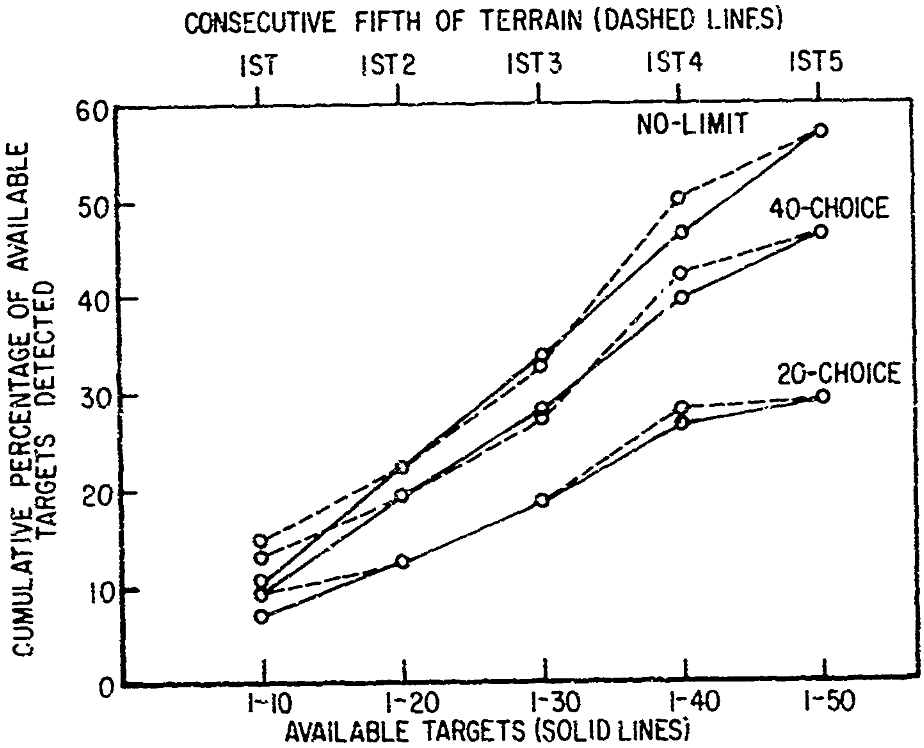

Figure 7. Rate of Accumulation of Target Detections as Shown by Percentage of Available Targets Found up Through Consecutive Tenths of the Available Targets and up Through Consecutive Fifths of the Strip of Terrain.

VARIATION IN ACCURACY OVER THE COURSE OF THE SIMULATED MISSION

Previously, it was shown that over the entire flight path, i.e., for the simulated mission taken as a whole, higher accuracies were obtained when fewer target choices were permitted. The flight path may be divided into sections on the basis of either length or of number of targets to examine accuracy as a function of degree of completion of the mission. Target selection behavior

TABLE IX

MEAN PERCENTAGE* AND CUMULATIVE PERCENTAGE OF TARGETS DETECTED IN EACH CONSECUTIVE FIFTH OF THE TERRAIN

		TEST GROUP					
Fifth of Terrain	Available Targets	20-Choice Mean%	20-Choice Sum%**	40-Choice Mean%	40-Choice Sum%	No-Limit Mean%	No-Limit Sum%
First	14	9.43	9.43	13.00	13.00	14.71	14.71
Second	6	3.00	12.43	6.29	19.28	7.57	22.29
Third	9	6.14	18.57	8.00	27.28	10.43	32.71
Fourth	16	9.57	28.14	15.00	42.28	17.57	50.29
Fifth	5	1.29	29.43	4.29	46.57	6.71	57.00
Sum	50	29.43	--	46.58	--	56.99	--

* Based on the 50 targets that were each detected by one or more of the 42 test subjects, not on the numbers in individual fifths of terrain.

** Sum % is the percentage of the total 50 targets detected up through the fifth of the terrain (3rd, etc.)

TABLE X

MEAN PERCENTAGE AND CUMULATIVE PERCENTAGE OF THE TOTAL OF 50 TARGETS THAT WERE DETECTED IN EACH CONSECUTIVE GROUP OF 10 DETECTABLE* TARGETS

	TEST GROUP					
Targets	20-Choice Mean%	20-Choice Sum%	40-Choice Mean%	40-Choice Sum%	No-Limit Mean%	No-Limit Sum%
1-10	6.857	6.857	9.143	9.143	10.286	10.286
11-20	5.571	12.428	10.143	19.286	12.000	22.286
21-30	6.143	18.571	9.000	28.286	11.286	33.572
31-40	8.000	26.571	11.571	39.857	13.000	46.572
41-50	2.857	29.428	6.714	46.571	10.429	57.001
Sum	29.428	--	46.571	--	57.001	--

* Detectable in that one or more of the 42 subjects recorded them as targets.

could change during the mission. Test subjects could become more cautious or less cautious in selecting targets, depending upon how rapidly they decide that they are using up their allowed number of choices.(or strike weapons) Subjects may, early in a mission, develop expectancies about frequency of occurrence of targets that will influence their selection behavior. This was discussed at length in the section on Distribution of Responses Over the Terrain.

Target visibility, or ease and certainty of finding and recognizing targets, will normally vary during the course of a simulated mission. This is a source of variability in accuracy in addition to accuracy changes that are attributable to changes in the degree of caution or selectivity of the observer. The numerical value of the accuracy is influenced by many variables that were unmeasured and/or uncontrolled. Thus, it is of interest to compare the accuracies of the various test groups.

The average accuracy for each choice group for successive fifths of the terrain is given in table XI and is plotted in figure 8. Although there are fluctuations, the accuracy curves for the no-limit and the 40-choice groups clearly do not exhibit any overall trend. For the 20-choice group, accuracy increases with the duration of the simulated mission. The linear component of this positive trend is shown to be a non-chance occurrence if the correlation between accuracy and fifth of the terrain is significantly different from zero. The product moment correlation was +.849. It became +.862 when normalizing requirements were satisfied by subjecting the data to an arc sine transformation. Since a correlation of only .805 is required for statistical significance at the .05 level, the obtained trend can not be attributed to chance.

TABLE XI

AVERAGE ACCURACY OF RESPONSES PER FIFTH OF THE STRIP OF TERRAIN FOR THE THREE TEST GROUPS

EXPERIMENTAL GROUP	FIFTH OF THE STRIP OF TERRAIN					OVERALL MEAN
	FIRST	SECOND	THIRD	FOURTH	FIFTH	
20-Choice	.6957	.5774	.7429	.9531	.9523	.7485
40-Choice	.6614	.6083	.6083	.7143	.5581	.6208
No-Limit	.3827	.3381	.4206	.4837	.3049	.3849

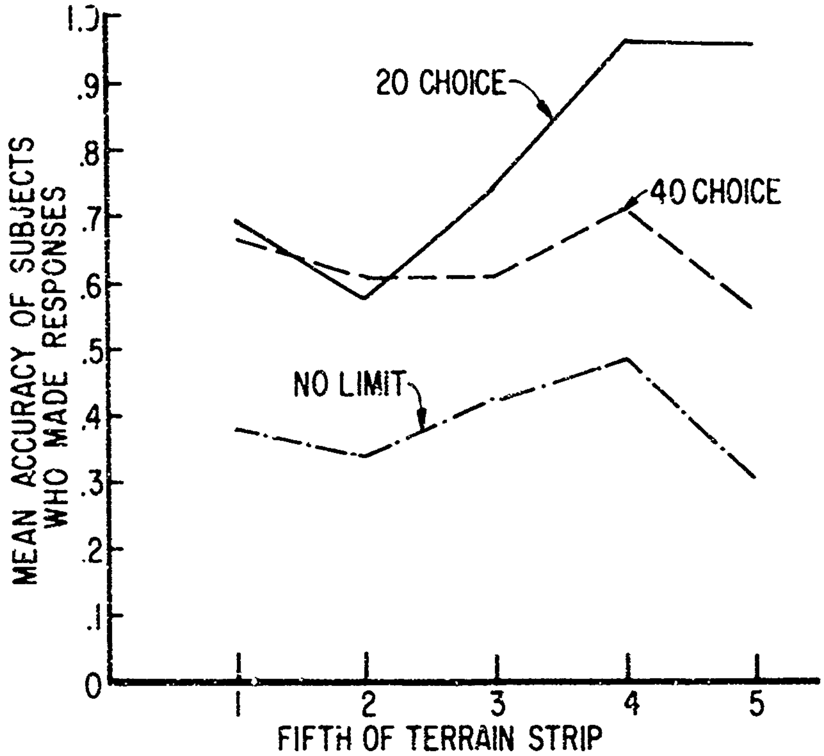

Figure 8. Average Accuracy by Fifths of Terrain for the Three Test Groups.

The 40-choice and the no-limit groups did not exhibit a trend in accuracy with duration of the simulated mission; hence, it is likely that average target visibility did not change appreciably during the flight. Possibly the 40-choice and no-limit groups became less cautious as the experiment progressed, and if average visibility of targets also increased, then accuracy might not appreciably alter during the test session. These possibilities are deemed unlikely. For these two groups, it is also unlikely that caution increased but target visibility decreased, so that no trend occurred in accuracy. It is concluded that the observers with only 20 allowed choices tended to become more cautious as the duration of the flight increased. Presumably, expectancies built up during the early parts of the simulated mission led them to believe that they could afford to be more selective in what they designate as targets and still be able to wisely expend all of their weapons.

It appears reasonable to expect that accuracy will increase as the number of unused choices decreases. To examine this possibility for the 20-choice group, accuracy was plotted against the number of choices that had been made (see fig 9). No strong trend is apparent in this figure, but the average of the last third of the curve is well above the average for the first third. Thus, a weak trend may be present. To examine this possibility, the product moment correlation between accuracy and number of choices made, using untransformed scores, was calculated. It is +.477, which is larger than the .378 value

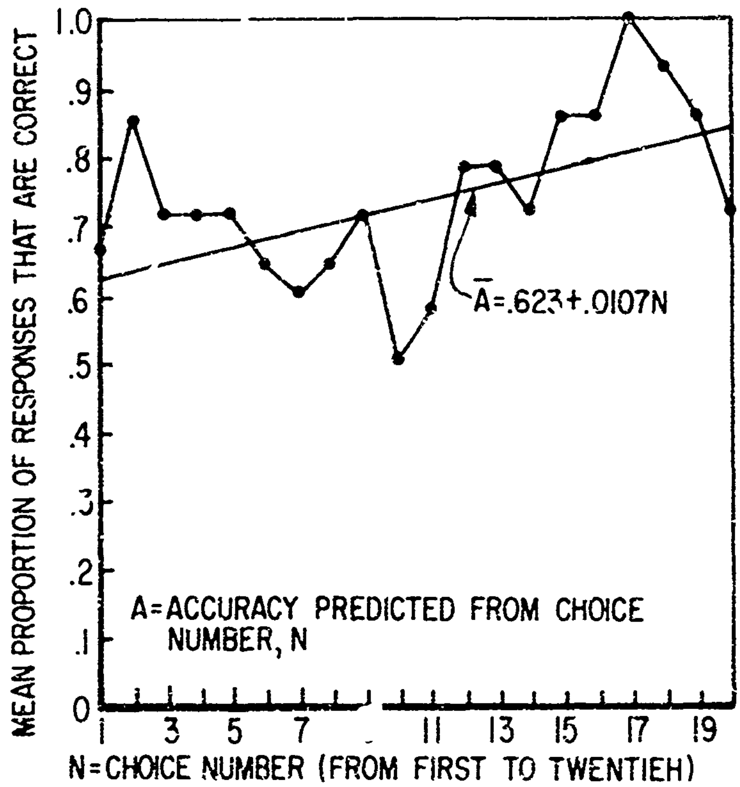

Figure 9. Average Accuracy from the First to Twentieth Choice for the 20-Choice Group.

required for statistical significance at the .05 level. It s concluded that a positive but not high degree of relationship exists between accuracy and number of choices that have been made. This finding is consistent with the positive relationship found for the 20-choice group between accuracy and mission duration as measured by successive fifths of terrain.

SCREEN TRAVEL

The distance that the image of an object moves down the display screen before the observers points to it and labels it according to target type, is called screen travel. The average screen travel for the three test groups is shown in table XII. Bartlett's test for homogeneity of K variances revealed no statistically significant heterogeneity of variance in the screen travel of detected targets (correct choices), or in the screen travel of false positives (incorrect choices). The hypothesis that the populations represented by the correct choice data have equal variances is acceptable, as is the hypothesis that population variances are equal for the screen travel of false positives.

The average distances (means) traveled by real targets prior to a response, as shown in the table, were similar for all three of the choice groups. The analysis of variance of mean distance traveled is given in table XIII. It shows

TABLE XII

AVERAGE DISTANCE* TRAVELED BY TARGET IMAGES BETWEEN THEIR INITIAL APPEARANCE ON THE DISPLAY A D THEIR DETECTION

Test Group	Mean	Standard Deviation
20-Choice	5.29	.86
40-Choice	5.48	.94
No-Limit	4.95	1.03

* Distances are in inches on the screen.

TABLE XIII

ANALYSIS OF VARIANCE FOR DISTANCE TRAVELED BY TARGETS PRIOR TO DETECTION

Source of Variance	d.f.	Mean Square	*F*	Meaning
Weapon load	2	0.6414	0.7166	The number of choices available had no significant effect upon the average distance traveled by targets prior to their detection.
Within groups variation	39	0.8951		
Total	41			

Note: Statistical significance at the .05 level was not attained.

that distances (reaction times) did not differ significantly for the three choice groups. The mean distances were subjected to multiple comparisons by use of Duncan's Test (NMRT). The same analysis was then performed on the mean distances traveled by false positives. In neither case was statistical significance achieved at the .05 level. It is concluded that the number of allowed choices (responses) has no significant effect upon the average distance traveled on the display, prior to detection, by the images of either real targets or of objects mistaken for targets. In brief, response to targets is equally rapid for the three test groups, as is the case for false positives.

For all three of the test groups the majority of the targets that are found are detected while still on the upper half of the display screen. This is clearly shown in figure 10.

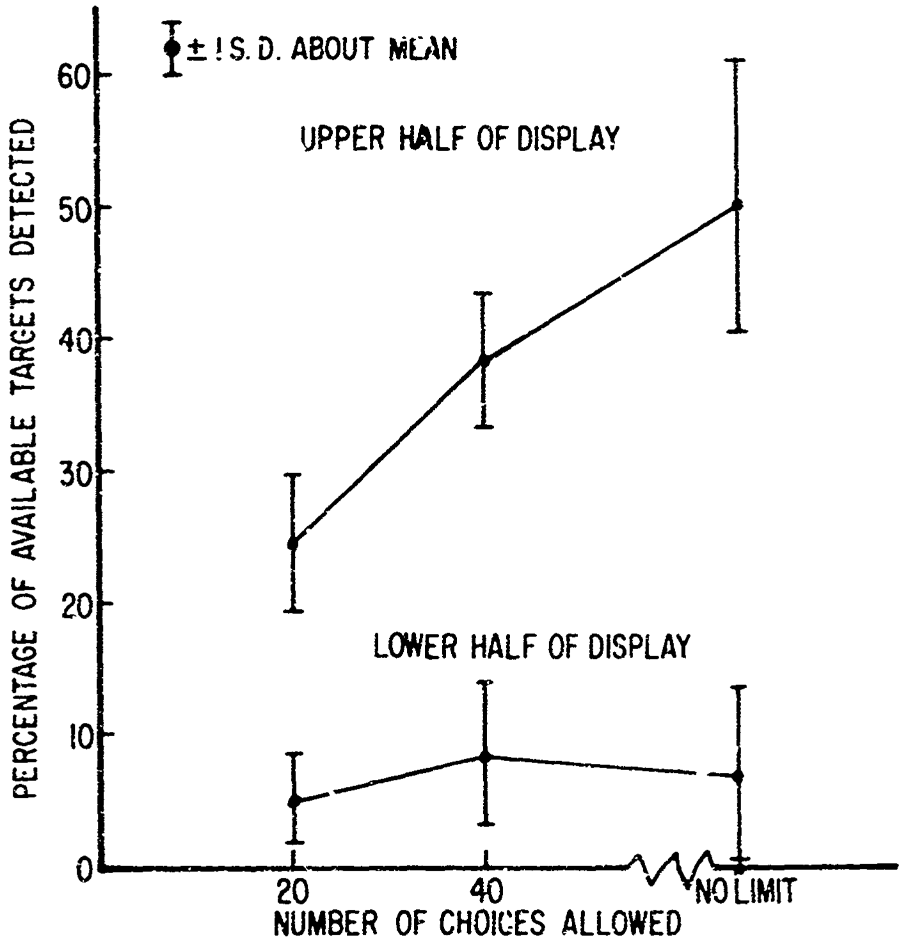

Figure 10. Percentage of Available Targets That Were Detected on the Upper and Lower Halves of the Display Screen. In Both Cases Fifty Targets Were Available.

DETECTABILITY OF DIFFERENT TYPES OF TARGETS

The general rule that the detectability of targets varies with the type of target applies to the performance of observers using a side-looking radar sensor. Table XIV lists the numbers of targets detected and the means and percentages of targets detected for the various types of targets. Figure 11 shows the results: For all four types of targets, the percentage detected increases as the number of allowed target choices increases. Note that performance against tank farms was consistently low relative to performance against other types of targets. Even with no limit placed upon the number of allowed target choices, only 19.1 percent of tank farms were detected. Except for the 20-choice group, percentage of targets detected was highest for railroad yards, reaching 66.8% for the no-limit group. Note the cross-over in figure 11 in the curve for airfields, and the slow increase in detections for airfields and tank farms, as compared to railroad yards and dams, with increase in the number of target choices that were allowed.

TABLE XIV

TARGET DETECTION FOR THE FOUR TYPES OF TARGETS

Target Type	Targets Present	TEST GROUP								
		20-CHOICES			40-CHOICES			NO LIMIT		
		N+	Mean	%*	N+	Mean	%	N+	Mean	%
Airfield	15	72	5.143	34.29	87	6.214	41.43	98	7.000	46.67
Dam	16	46	3.286	20.54	101	7.214	45.03	122	8.714	54.46
RR Yard	14	61	4.357	31.12	102	7.286	52.04	131	9.357	66.84
Tank Farm	18	27	1.928	10.71	36	2.571	14.29	48	3.429	19.05
Sum	63	206	--	--	326	--	--	399	--	--
Mean	--	14.714	--	--	23.286	--	--	28.500	--	--

+N is number of targets detected by the entire 14 subjects in the test group.

* Percentages are based on the 63 targets determined, prior to testing subjects to have detectable and recognizable target signatures. If percentage values in the table are multiplied by 63/50, i.e. by 1.26, the results will be percentage detection against the 50 targets found by one or more of the 42 subjects.

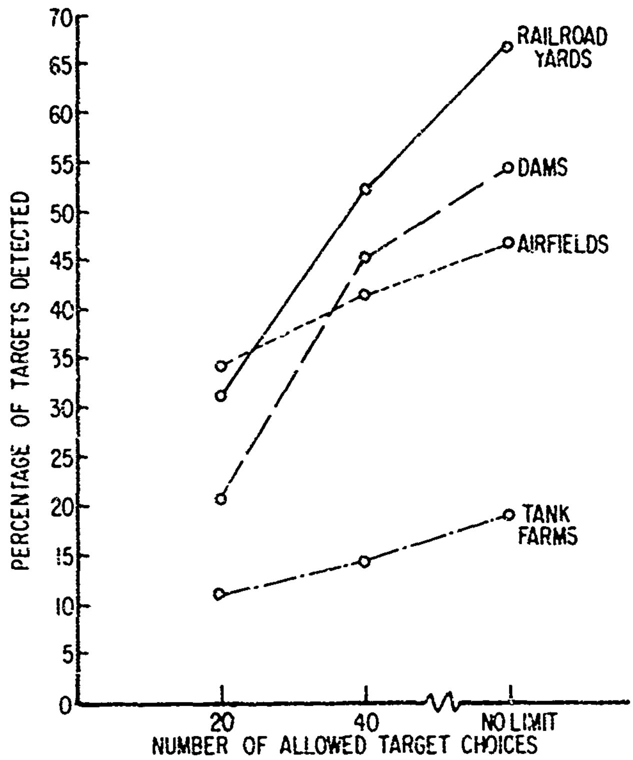

Figure 11. Percentage of Targets of Different Types Detected.

ACCURACY FOR DIFFERENT TYPES OF TARGETS

In an earlier section of this paper, overall accuracy, where performance against all types of targets was pooled, was found to rapidly decrease as number of target choices increased. What happens for different types of targets should be examined for more insight into the overall decrease in accuracy. For example, it would be important to know whether or not the accuracy loss could be attributed to only one or two types of targets. The accuracy data given in table XV is plotted in figure 12. Note that with a slight exception for dams, the rate of decrease of proportion of responses that were correct, as shown by the steepness or slope of the curves, is about the same for the different types of targets. Apparently, no one type of target is particularly responsible for the large increase in errors that occurs when more target choices are permitted. In figure 12, the big drop in accuracy over the three test conditions occurs in going from the 40-choice to the no-limit condition.

Table XV and figure 12 show that accuracy is highest for airfields: from .97 (with 20-choices) to .70 (with no limit on number of choices) of objects called airfields by the observers are truly airfields. Clearly, few objects of other types are mistaken for airfields. This is in sharp contrast to tank farms where accuracy was lowest. With proportion of responses that were correct of .54

to .17 for the extreme conditions, an object identified as a tank farm is probably something else. When numbers of choices were unlimited, only airfield and dam responses (designations) were more likely to be correct than incorrect. Note that performance on tank farms was lowest for the no-limit choice group as measured by either accuracy or percentage of targets detected. Also, railroad yards, while high on percentage detected, were relatively low on response accuracy: Most of them were found, but other objects were often mistaken for them.

TABLE XV

ACCURACY BY TARGET TYPE FOR THE THREE TEST GROUPS

TEST GROUP	TYPE OF TARGET			
	AIRFIELDS	DAMS	RR YARDS	TANK FARMS
20-Choice	.9673	.8151	.7120	.5429
40-Choice	.9123	.6301	6200	.4158
No-Limit	.7005	.5784	.4003	.1678

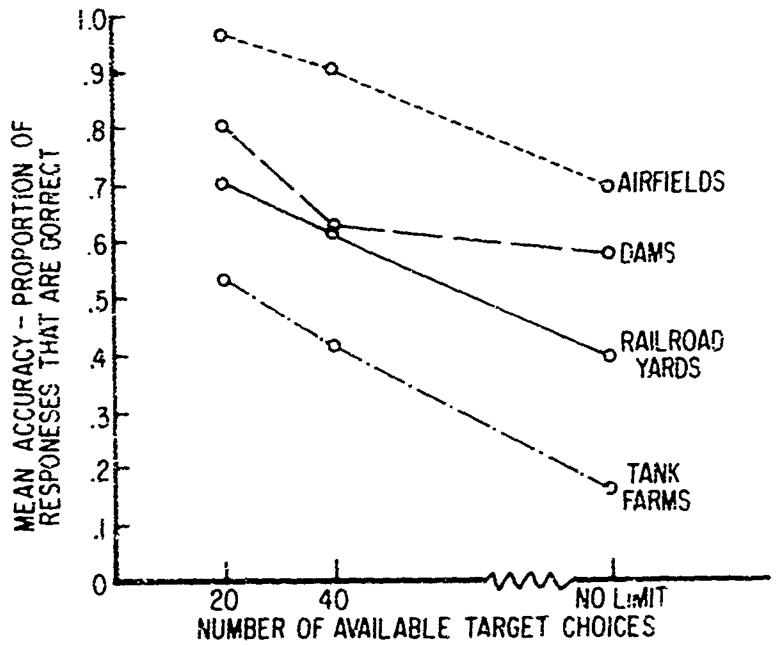

Figure 12. Accuracy Versus Number of Available Target Choices for the Four Different Types of Targets.

EFFECT OF TEST CONDITIONS ON DIFFERENT TYPES OF TARGETS

Figure 13 and table XVI show the number of different targets of each type reported by one or more individuals. With each increase in number of choices allowed, there was an increase in the number of different targets of each type reported. Clearly, this increase was in individual targets not reported by anyone in the more restricted test groups. When all types of targets were combined, the unlimited choice group reported 44% more different targets than did the 20-choice group.

Figure 13 shows that when allowed number of choices increases greatly, there is only a small increase in the number of reported different railroad yards and airfields. However, there is a large increase in different dams and tank farms. Thus, restricting number of allowed choices had a differential influence upon the detection of the different types of targets. The targets not reported at all in the two limited-choice groups were responded to infrequently in the unlimited choice group. They were likely the targets that were the most difficult to find and/or were less obviously targets when they were found.

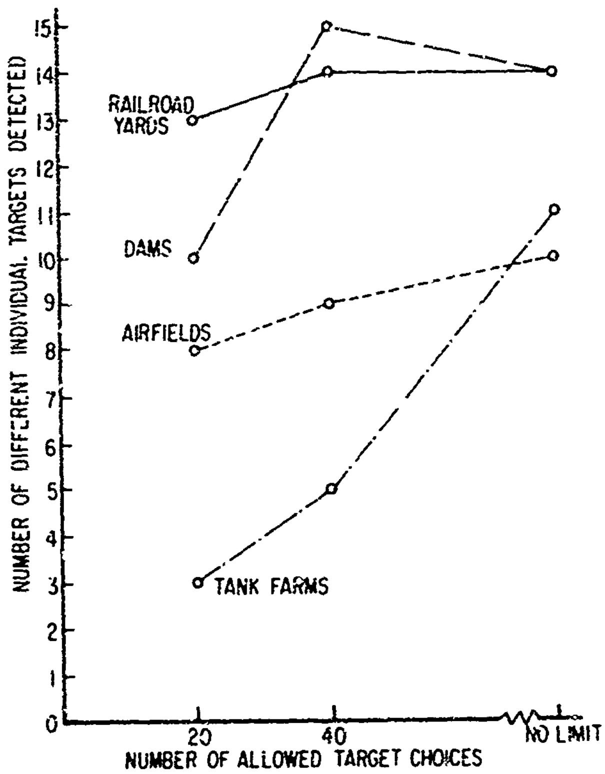

Figure 13. **Number of Different Targets of Each Type Detected With Different Numbers of Allowed Target Choices.**

TABLE XVI

NUMBER OF DIFFERENT TARGETS OF EACH TYPE DETECTED

Target Type	NUMBER DETECTED BY THE 14 TEST SUBJECTS IN EACH GROUP — TEST GROUP: 20-Choices	40-Choices	No-Limit	Different Targets Present*
Airfield	8	9	10	15
Dam	10	15	14	16
RR Yard	13	14	14	14
Tank Farm	3	5	11	18
Sum	34	43	49	63
Mean/Subject	2.43	3.07	3.50	

* As determined by image truth prior to testing subjects, i.e., prejudged as being detectable.

SECTION IV

RECOMMENDATIONS

An unacceptably high proportion of false-positives has been found in numerous studies by the present authors and by other investigators. These studies have presented images of the real world to observer and have usually placed little or no restrictions upon the number of targets that observers could designate. Obviously some errors are due to marginally resolved target and to nontarget images. The present study demonstrates that limiting the number of targets that may be chosen can greatly reduce the number and proportion of nontargets that are reported as targets. This reduction is understandably achieved at a cost in the percentage of actual targets detected. Despite this, the study shows that response restrictions could make useful some rapid reconnaissance and reconnaissance/strike systems that may have appeared, on the basis of prior studies and analyses, to be feasible because of high false-positive rates. Thus, the following recommendations are made:

1. Since the false-positive rates in studies without realistic limits on number of responses allowed are misleading. These results must be interpreted in the light of the findings of the present study.

2. Reconnaissance and reconnaissance/strike systems studies should impose realistic limitations on number of allowed target choices.

3. The realizable potentials for target finding systems that can result from use of appropriate instructions and orientation, from efficient utilization of confidence judgment information, and from optimum restrictions upon the number of permitted target choices is unknown. More information is necessary on the utility-of-choice restrictions versus confidence judgments. This can be obtained in studies using the same stimulus materials. Trade-off information from such studies is needed by training and using organizations dealing with images of the real world.

APPENDIX

INSTRUCTIONS TO THE TEST SUBJECTS

INSTRUCTIONS

This mission flies over hostile territory at a speed of 1320 knots for 27 minutes. The picture, covering a 14 by 14-inch screen, depicts a strip of ground 25 nautical miles wide. The image moves down the screen at about 12 inches per minute. The targets, as shown by the illuminated push buttons, are:

Airfields

Dams

Railroad Yards

Tank Farms

When you find a target, depress the proper target name switch, place the tip of the illuminated pointer on the target, and press the "record" switch to allow the data camera to record your response. Be sure at that time that your head or shoulder does not block the view of the camera. Do not be too cautious to attack targets, but be careful not to waste weapons on nontarget objects, i.e., before launching a weapon, be fairly sure that you are aiming at a target.

INSTRUCTIONS

This mission flies over hostile territory, at a speed of 1320 knots for 27 minutes. The picture, on a 14 by 14-inch screen, depicts a strip of ground 25 nautical miles wide. The image moves down the screen at about 12 inches per minute. The targets as shown by the illuminated push buttons, are:

Airfields

Dams

Railroad Yards

Tank Farms

Your aircraft carries 20 bombs (or missiles). Your task is to make the best use of them: Do not be too cautious to attack targets, but be careful not to waste weapons on nontarget objects, i.e., before launching a weapon, be fairly sure that you are aiming at a target. Bringing a weapon back to home base is preferable to wasting it on a nontarget. You will not be told how many targets are on the filmstrip.

A clock and a counter on the console always display the time and the number of weapons remaining; check both of them occasionally, as well as the list of target push buttons, to keep track of target types, times and munitions.

When a target is found, depress the proper target name switch, place the illuminated pointer's tip on the target, and push the "record" switch to record the target choice. Be sure at that time that your head or shoulder does not block the view of the camera.

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